INDOOR AIR QUALITY ASSESSMENT

Clinton Town Hall
242 Church Street
Clinton, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
November 2005

Background/Introduction

At the request of William Dickhaut, Health Inspector for the Clinton Board of Health, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality concerns at the Clinton Town Hall (CTH), 242 Church Street, Clinton, MA. General complaints by building occupants of poor air exchange and temperature control due to the malfunctioning of the heating, ventilating and air conditioning (HVAC) system prompted the request.

On July 14, 2005, a visit to conduct an indoor air quality assessment was made to the CTH by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by Mike Ward, Town Administrator, and Mr. Dickhaut for portions of the assessment.

The CTH is a two-story, brick building containing an occupied basement and constructed in 1909. The building underwent renovations from 1994 to 1996. The building has a peaked, slate-shingled roof with a bell tower in the center. Windows are openable throughout the building. The building contains town offices and public meeting rooms.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The CTH has an employee population of approximately 30 to 35 and is visited by approximately 100 to 150 individuals daily. The tests were taken during normal operations. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were below 800 ppm (parts per million) in all areas surveyed, indicating adequate ventilation in the building. Fresh, heated air is supplied by air-handling units (AHUs) located in mechanical rooms. Conditioned air is delivered to occupied areas via ceiling or wall-mounted air diffusers (Picture 1). Return air is drawn into the main hallway via passive wall vents (Picture 2) into a return vent ducted back to the AHU (Pictures 2 and 3). Although the request for this assessment was prompted by the malfunction of the buildings HVAC system, Mr. Dickhaut reported that the HVAC system was repaired several days prior to the CEH visit. The system was operating during the assessment.

The CTH was originally configured to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window (called a transom, Picture 4) enables building occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through an office and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open office transom, into the opposing room and finally exits the building on the leeward side (opposite the windward side) (Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or transoms are closed (Figure 2). Although some transoms were open during the assessment (Picture 4), others were closed.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please refer to Appendix A.

Temperature readings ranged from 70^{o} F to 76^{o} F, which were within the MDPH recommended comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. As discussed, the assessment was prompted due to malfunctions with the mechanical ventilation system. As mentioned previously, the HVAC system was repaired prior to the MDPH assessment. Mr. Dickhaut reported no further temperature and/or comfort complaints since the system had been repaired. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the building ranged from 53 to 72 percent, with readings above the MDPH recommended comfort range in several areas. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. While temperature is mainly a comfort issue, relative humidity in excess of 70 percent for extended periods of time, can provide an environment for mold and fungal growth (ASHRAE, 1989). During periods of high relative humidity (late spring/summer months), windows and exterior doors should be closed as much as possible to keep moisture out. In addition, areas that are equipped with air conditioning should keep their doors shut to prevent conditioned air from entering the unconditioned hallways to prevent condensation on the cool surface of hallway floors. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Water damaged wall plaster, peeling paint and efflorescence were observed on ceilings and walls in the men's ground floor restroom (Pictures 4 and 5). Water damage and efflorescence are most likely the result of water penetration through the building envelope. Missing/damaged mortar was observed around brick on the exterior wall outside the men's room (Picture 6). Efflorescence is a characteristic sign of water damage to brick and mortar, but it is not mold growth. As moisture penetrates and works its way through mortar and brick, water-soluble compounds in mortar and brick dissolve, creating a solution. As the solution moves to the surface of the mortar or brick, the water evaporates, leaving behind white, powdery mineral deposits.

Water damaged wall plaster was noted in the selectmen's secretary's office (Picture 7). In this case CEH staff found the bulkhead at the top of the bell tower had been left open (Picture 8) which appeared to allow rainwater penetration, causing the water damage seen in the office. An open utility hole also exists in the bell tower roof (Picture 9), which can serve as another source for water penetration. Water-damaged porous materials can provide a source of mold and should be repaired/replaced after a moisture source is discovered and repaired.

A few areas had water damaged ceiling tiles (Picture 10). Water-damaged ceiling tiles can be a medium for mold growth. The ceiling tiles should be replaced after a water leak is discovered.

Conclusions/Recommendations

In view of the findings at the time of this assessment, the following recommendations are made:

1. Consider consulting with an architect, masonry firm or general contractor regarding the integrity of the building envelope, primarily concerning water penetration through exterior walls. Ensure all leaks are repaired. Once leaks are repaired, repair water-damaged plaster/paint and examine the feasibility of repointing brickwork.
2. Ensure bell tower bulkhead door is kept shut. Seal utility hole in bell tower roof to prevent water penetration.
3. Balance mechanical ventilation systems every five years, as recommended by ventilation industrial standards (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
4. This building was originally designed to use windows in combination with transoms to provide air exchange. Use openable windows in conjunction with mechanical ventilation to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.

5. Ensure leaks are repaired and replace water damaged ceiling tiles. Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g. throat and sinus irritations).
7. Clean supply/return vents periodically of accumulated dust.
8. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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Appendix A

Carbon Dioxide and its Use in Evaluating Adequacy of Ventilation in Buildings

The Center of Environmental Health's (CEH) Emergency Response/Indoor Air Quality (ER/IAQ) Program examines indoor air quality conditions that may have an effect on building occupants. The status of the ventilation system, potential moisture problems/microbial growth and identification of respiratory irritants are examined in detail, which are described in the attached report. In order to examine the function of the ventilation system, measurements for carbon dioxide, temperature and relative humidity are taken. Carbon dioxide measurements are commonly used to assess the adequacy of ventilation within an indoor environment.

Carbon dioxide is an odorless, colorless gas. It is found naturally in the environment and is produced in the respiration process of living beings. Another source of carbon dioxide is the burning of fossil fuels. Carbon dioxide concentration in the atmosphere is approximately 250-600 ppm (NIOSH, 1987; Beard, 1982).

Carbon dioxide measurements within an occupied building are a standard method used to gauge the adequacy of ventilation systems. Carbon dioxide is used in this process for a number of reasons. Any occupied building will have normally occurring environmental pollutants in its interior. Human beings produce waste heat, moisture and carbon dioxide as by-products of the respiration process. Equipment, plants, cleaning products or school supplies normally found in any school can produce gases, vapors, fumes or dusts when in use. If a building has an adequately operating mechanical ventilation system, these normally occurring environmental pollutants will be diluted and removed from the interior of the building. The introduction of fresh air both increases the comfort of the occupants and serves to dilute normally occurring environmental pollutants.

An operating exhaust ventilation system physically removes air from a room and thereby removes environmental pollutants. The operation of univents in conjunction with the exhaust ventilation system creates airflow through a room, which increases the comfort of the occupants. If all or part of the ventilation system becomes non-functional, a build up of normally occurring environmental pollutants may occur, resulting in an increase in the discomfort of occupants.

The MDPH approach to resolving indoor air quality problems in schools and public buildings is generally two-fold: 1) improving ventilation to dilute and remove environmental pollutants and 2) reducing or eliminating exposure opportunities from materials that may be adversely affecting indoor air quality. In the case of an odor complaint of unknown origin, it is common for CEH staff to receive several descriptions from building occupants. A description of odor is subjective, based on the individual's life experiences and perception. Rather than test for a potential series of thousands of chemicals to identify the unknown material, carbon dioxide is used to judge the adequacy of airflow as it both dilutes and removes indoor air environmental pollutants.

As previously mentioned, carbon dioxide is used as a diagnostic tool to evaluate air exchange by building ventilation systems. The presence of increased levels of carbon dioxide in indoor air of buildings is attributed to occupancy. As individuals breathe, carbon dioxide is exhaled. The greater the number of occupants, the greater the amount of carbon dioxide produced. Carbon dioxide concentration build up in indoor environments is attributed to inefficient or non-functioning ventilation systems. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

Carbon dioxide can be a hazard within enclosed areas with **no air supply**. These types of enclosed areas are known as confined spaces. Manholes, mines and sewer systems are examples of confined spaces. An ordinary building is not considered a confined space. Carbon dioxide air exposure limits for employees and the general public have been established by a number of governmental health and industrial safety groups. Each of these standards of air concentrations is expressed in parts per million (ppm). *Table 1* is a listing of carbon dioxide air concentrations and related health effects and standards.

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings (SMACNA, 1998; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990). A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Several sources indicate that indoor air problems *are significantly reduced* at 600 ppm or less of carbon dioxide (ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH, 1987). Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Appendix A

Air levels for carbon dioxide that indicate that indoor air quality may be a problem have been established by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). Above 1,000 ppm of carbon dioxide, ASHRAE recommends adjustment of the building's ventilation system (ASHRAE, 1989).

Carbon dioxide itself has no acute (short-term) health effects associated with low level exposure (below 5,000 ppm). The main effect of carbon dioxide involves its ability to displace oxygen for the air in a confined space. As oxygen is inhaled, carbon dioxide levels build up in the confined space, with a decrease in oxygen content in the available air. This displacement of oxygen makes carbon dioxide a simple asphyxiant. At carbon dioxide levels of 30,000 ppm, severe headaches, diffuse sweating, and labored breathing have been reported. No **chronic** health effects are reported at air levels below 5,000 ppm.

Air testing is one method used to determine whether carbon dioxide levels exceed the comfort levels recommended. If carbon dioxide levels are over 800-1,000 ppm, the MDPH recommends adjustment of the building's ventilation system. The Department recommends that corrective measures be taken at levels above 800 ppm of carbon dioxide in office buildings or schools. (Please note that carbon dioxide levels measured below 800 ppm may not decrease indoor air quality complaints). Sources of environmental pollutants indoors can often induce symptoms in exposed individuals regardless of the adequacy of the ventilation system. As an example, an idling bus outside a building may have minimal effect on carbon dioxide levels, but can be a source of carbon monoxide, particulates and odors via the ventilation system.

Appendix A

Therefore, the MDPH strategy of adequate ventilation coupled with pollutant source reduction/removal serves to improve indoor air quality in a building. Please note that each table included in the IAQ assessment lists CEH comfort levels for carbon dioxide levels at the bottom (i.e. carbon dioxide levels between 600 ppm to 800 ppm are acceptable and <600 ppm is preferable). While carbon dioxide levels are important, focusing on these air measurements in isolation to all other recommendations is a misinterpretation of the recommendations made in these assessments.

Appendix A

Table 1
Carbon Dioxide Air Level Standards

Carbon Dioxide Level	Health Effects	Standards or Use of Concentration	Reference
250-600 ppm	None	Concentrations in ambiant air	Beard, R.R., 1982 NIOSH, 1987
600 ppm	None	Most indoor air complaints eliminated, used as reference for air exchange for protection of children	ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH 1987
800 ppm	None	Used as an indicator of ventilation inadequacy in schools and public buildings, used as reference for air exchange for protection of children	Bell, A. A., 2000; SMACNA, 1998; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990
1000 ppm	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1989
950-1300 ppm*	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1999
5000 ppm	No acute (short term) or chronic (long-term) health effects	Permissible Exposure Limit/Threshold Limit Value	ACGIH, 1999 OSHA, 1997
30,000 ppm	Severe headaches, diffuse sweating, and labored breathing	Short-term Exposure Limit	ACGIH, 1999 ACGIH. 1986

* outdoor carbon dioxide measurement +700 ppm

Appendix A

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Appendix A

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National Association, Inc.

Picture 1

Ceiling-Mounted Air Diffuser

Picture 2

Passive Vent on Left Wall, Central Return Vent on Right Wall

Picture 3

Close-Up of Central Return Vent

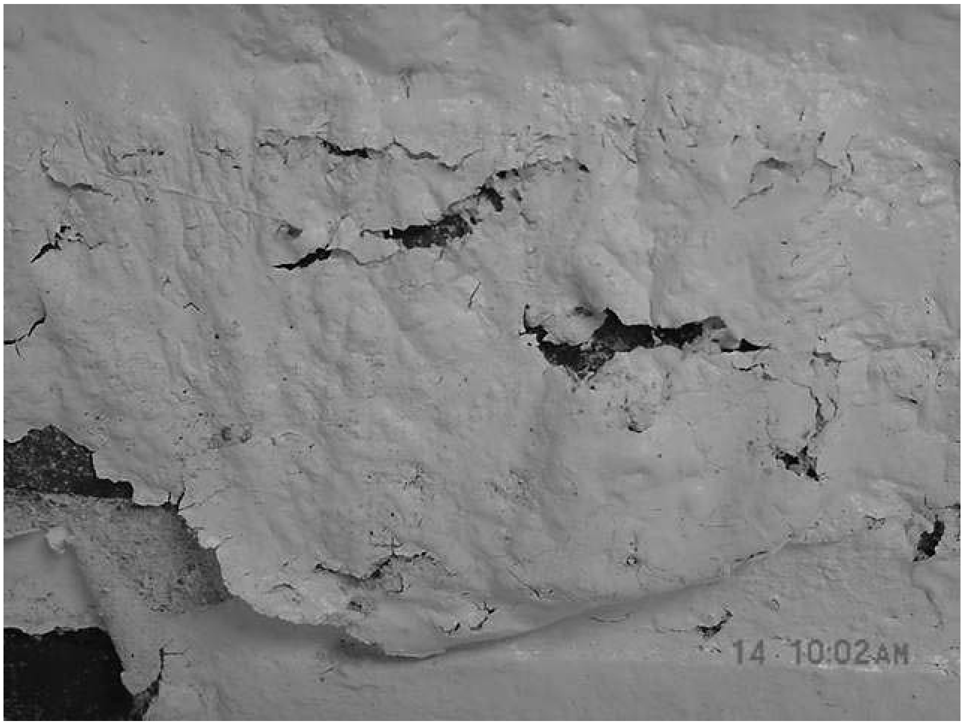
Picture 4

Transom in Use

Picture 5

Peeling Paint and Efflorescence in the Ground Floor Men's Room

Picture 6

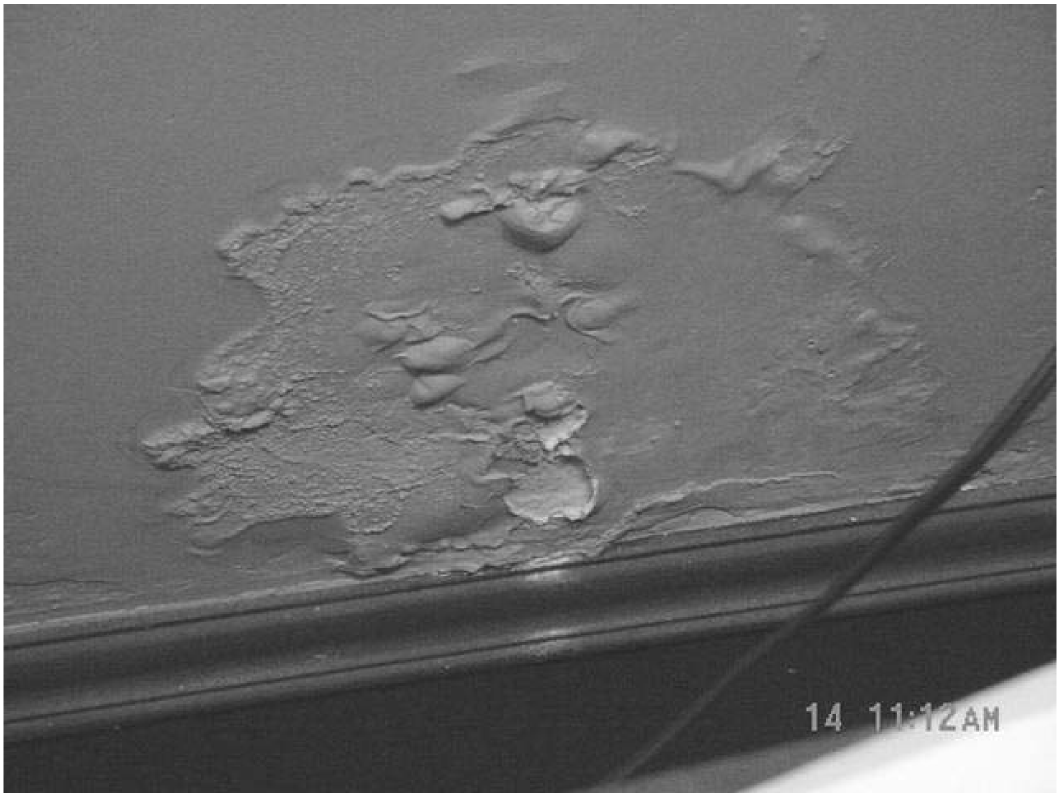


Close-Up of Peeling Paint and Efflorescence in the Ground Floor Men's Room

Picture 7

Missing/Damaged Mortar around Brick outside Ground Floor Men’s Room, Note Moss Growth Indicating Chronic Moisture

Picture 8



Peeling Paint and Efflorescence in the Selectmen's Secretary's Office

Picture 9

Open Bulkhead in Bell Tower

Picture 10

Open Utility Hole in Bell Tower Roof

Picture 11

Water Damaged Ceiling Tiles in Ground Floor

TABLE 1

Indoor Air Test Results – Clinton Town Hall, 242 Church Street, Clinton MA **July 14, 2005**

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	438	81	81					Overcast, humid, winds light and variable
Board of Health	719	74	53	2	Y	Y	Y	Passive exhaust vent to hallway, DO
DPW	651	74	56	1	Y	Y	N	DO
Meeting Room	662	71	56	0	Y	Y	Y	4 CT-radiator leak, on work order for repair
Ladies Room	507	70	69	0	N	N	Y	Exhaust ventilation-off
Men's Room	645	71	66	0	Y	N	Y	Exhaust ventilation-off/dusty, efflorescence water damaged plaster
Town Clerk	482	76	72	3	Y	Y	Y	Transoms in use, window open
Accountant	456	76	68	2	Y	Y	Y	Transoms open, DO, plants
Collector	494	76	72	1	Y	Y	Y	DO, window open

- **ppm = parts per million parts of air**
- **DO = door open, CT = water damaged ceiling tile**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results – Clinton Town Hall, 242 Church Street, Clinton MA **July 14, 2005**

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Auditorium	464	76	64	0	Y	Y	Y	
Chamber	443	76	61	0	Y	Y	Y	
Selectman's Secretary	489	73	65	1	Y	Y	Y	Water damage wall plaster
Veterans	463	73	63	1	Y	Y	Y	Weak airflow complaints
Perimeter								Missing/damaged mortar around brick outside men's room/moss growth, wood rot-Walnut ST auditorium doors (NW side), broken window pane-NW side, SE door

- **ppm = parts per million parts of air**
- **DO = door open, CT = water damaged ceiling tile**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

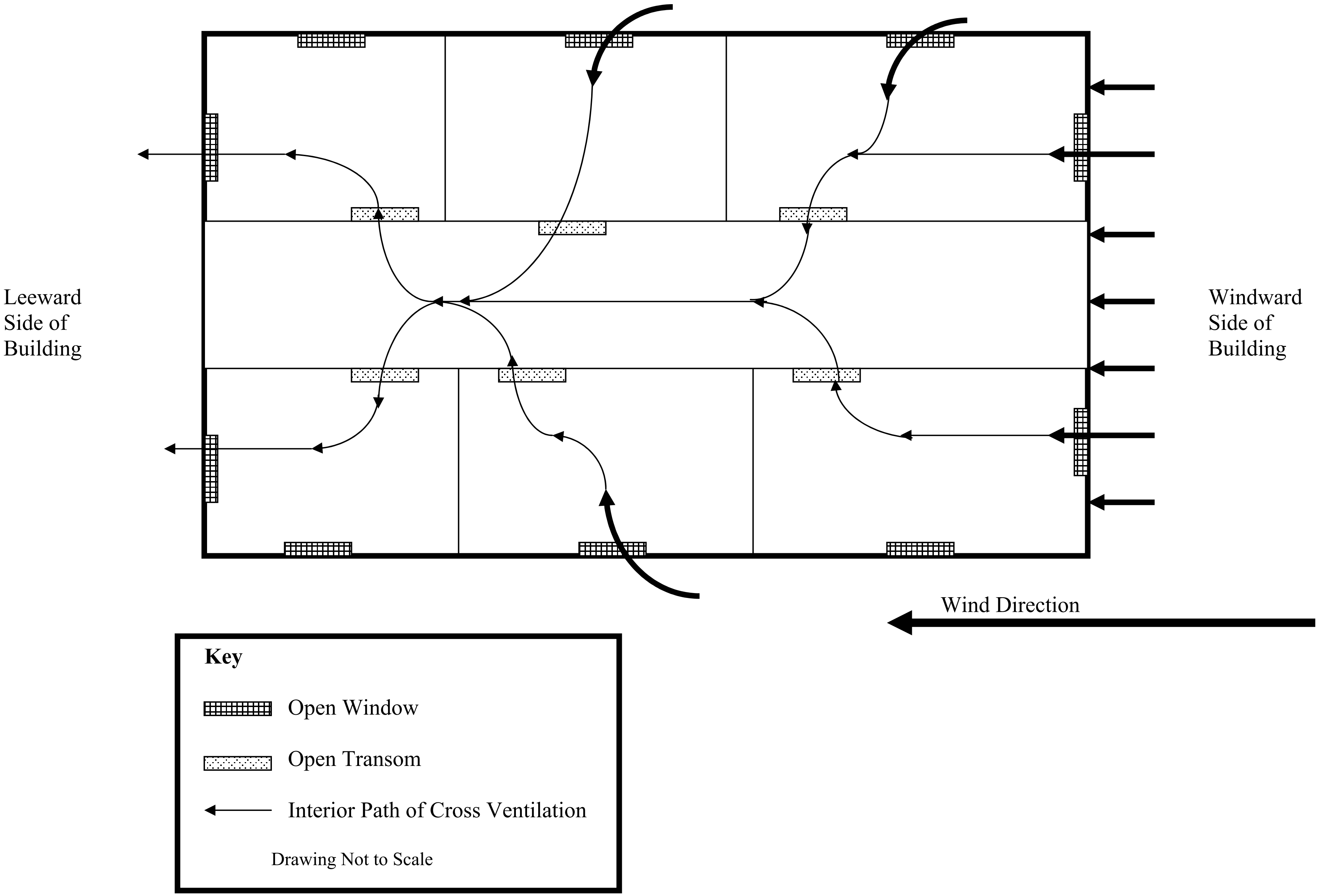


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**